CHAPTER FOUR

FATE OF AFLATOXINS AND FUMONISINS DURING THE PROCESSING OF MAIZE INTO FOOD PRODUCTS IN BENIN

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ABSTRTACT

The fate of aflatoxins and fumonisins, two mycotoxins that co-occur in maize, was studied through the traditional processing of naturally contaminated maize in *mawe*, *makume*, *ogi*, *akassa* and *owo*, maize-based foods common in Benin, West Africa. Levels of total aflatoxin and fumonisin were measured at the main unit operations of processing and the unit operations that induce significant reduction of mycotoxin level were identified. Overall reduction of mycotoxin level was more significant during the preparation of *makume* (93 % reduction of aflatoxins, 87 % reduction of fumonisins) and *akassa* (92 % reduction of aflatoxins, 50 % reduction of fumonisins) than that of *owo* (40 % reduction of aflatoxins, 48 % reduction of fumonisins). Sorting, winnowing, washing, crushing combined with dehulling of maize grains were the unit operations that appeared very effective in achieving significant mycotoxin removal. Fermentation and cooking showed little effect. During the preparation of *ogi* and *akassa*, reduction of fumonisin levels measured in food matrix was lower (50 %) compared to *mawe* and *makume*, probably due to significant fumonisin release in *ogi* supernatant. Consequently, the use of *ogi* supernatant for preparing beverages or traditional herbal medicines could be harmful as it is likely to be contaminated with mycotoxin from the raw maize.

Keywords: Maize, maize-based products, processing, aflatoxins, fumonisins, Benin.

INTRODUCTION

Aflatoxins and fumonisins are metabolites respectively produced by toxigenic species of *Aspergillus* and *Fusarium*, of which *A. flavus* and *A. parasiticus* (Diener *et al.* 1987, Pittet 1998) and *F. verticillioides* and *F. proliferatum* (Gelderblom *et al.* 1988, Keller *et al.* 1997) are by far the most important. Attention is increasingly given to these mycotoxins for several reasons. They have been shown to be directly responsible for several animal diseases. Aflatoxins are found to be hepatotoxic and potent hepatocarcinogens in animals (Wogan 1968, Wogan 1992). Fumonisins have been shown to be the causative agents of leukoencephalomalacia in horses (Kellerman *et al.* 1990) and pulmonary oedema syndrome in pigs (Harrison *et al.* 1990).

Aflatoxins and fumonisins are known to be hazardous to the health of humans, in some cases directly causing illness and even death. Aflatoxins are implicated in liver cancer (IARC 1993, JECFA 1998, Wild and Hall 2000). Chao *et al.* (1991) reported an incident when aflatoxins present in a foodstuff consumed by people in Malaysia in 1988 were strongly implicated as the cause of death of 13 children. Aflatoxins have been reported to impair childhood growth in children from Benin and Togo (Gong *et al.* 2002). Fumonisins were reported to be associated with oesophageal cancer in rural areas in South Africa (Rheeder *et al.* 1992) and China (Chu and Li 1994), and liver cancer in China (Ueno *et al.* 1997). Consumption of mouldy sorghum and maize containing fumonisin B_1 has been associated with an outbreak of abdominal pain and diarrhoea in India (Bhat *et al.* 1997).

Another important reason to be concerned is that these mycotoxins occur worldwide in maize, either alone or together (IARC 1993, Chamberlain *et al.* 1993, Marasas 1996, Shephard *et al.* 1996, Marin *et al.* 1999, Kpodo *et al.* 2000, Gelderblom *et al.* 2002). Maize is a dietary staple food in many countries in the world (Thiel *et al.* 1996). In Africa, maize is the cereal with highest production and consumption (ISAAA 2002). Per capita daily consumption of maize averages more than 246 g in Benin (Hounhouigan *et al.* 1999), 342 g in Kenya (ECAMAW 2002) and 488 g in South Africa (CIMMYT 2002). Maize is consumed in different forms in the world. Nago *et al.* (1997) reviewed traditional African maize products and found various forms including porridges, pastes, dumplings, cakes, fritters and beverages.

Effects of processing on mycotoxin contamination in food products are increasingly being investigated throughout the world and this strategy is showing great promise for mycotoxin reduction. The use of physical methods including cleaning, separation of screenings, washing, aqueous extraction, dehulling and milling, have been shown to be

effective, to a certain extent, in reducing mycotoxins in cereals (Sydenham *et al.* 1994, Charmley and Prelusky 1994, Voss *et al.* 1996, Shetty and Bhat 1999). Aflatoxin and fumonisin levels in tortillas were found to be significantly reduced due to alkaline cooking (Guzman de Pena *et al.* 1995, Dombrink-Kurtzman *et al.* 2000, Voss *et al.* 2001).

There is very little information concerning attempts to reduce mycotoxin contamination in maize using traditional processing methods in Africa, even though many maize-based food products exist. In Benin, about 40 different maize processing methods have been recorded (Nago 1997). The present research was carried out to determine the fate of both aflatoxins and fumonisins in naturally contaminated maize products and to identify operations that give a significant reduction in mycotoxin levels during processing.

Three traditional maize-based products commonly consumed in West Africa were used in this study. These were *mawe*, *ogi* and *owo*. *Mawe* is a solid state fermented dough used in Benin, Togo and Nigeria for cooking several dishes (Hounhouigan *et al.* 1993). One popular dish from *mawe* is *makume*, a thick paste consumed with stew. *Ogi* is a gruel obtained by fermentation of a suspension of wet-milled maize in water, processed into *akassa*, another thick paste and also consumed with stew (Hounhouigan 1994). It is also popular in West African countries. Steinkraus *et al.* (1983) reported a product similar to *ogi*, known as *uji* in Kenya. *Owo* is a non-fermented thick paste obtained from whole maize meal named *lifin*. It is a common and popular food in many African countries (Nago *et al.* 1997). A similar product to *owo* in South Africa is the stiff porridge (NIM. Somdyala, PROMEC, Tygerberg, South Africa, 2002, personal communication).

MATERIALS AND METHODS

Origin of maize samples

Maize, in three separate samples of 20 kg each collected from the same store, was obtained from the research station of Ina situated in the North of Benin. This was of the 90-day cultivar DMR-ESR-W, an improved IITA white variety. DMR-ESR-W is resistant to downy mildew (*Peronosclerospora sorghi*) and to maize streak virus (Schulthess *et al.* 2002).

Preparation of maize products

Preparation of *mawe*, *ogi* and *lifin* (whole maize meal) into derived products namely *makume, akassa* and *owo* respectively was executed using the expertise of four women, experienced in the production of these products.

Mawe was prepared following the traditional procedure indicated in Fig. 1 as described by Hounhouigan *et al.* (1993). Three replicates of 5 kg of maize (total fumonisin level = 1.99 ± 0.06 mg kg^{-1} and total aflatoxin level = 15.28 ± 0.32 µg kg^{-1} were sorted, winnowed and washed. Sorting consisted in removing visibly mouldy, insect-damaged and broken grains by hand. Winnowing, a complementary process to sorting, consisted in discarding the rest of impurities present in the sorted maize. Thus, a certain quantity of sorted maize was collected in a circular metallic tray, and thrown into the air by the operator allowing impurities and small broken grains to be blown away. Maize washing came after sorting and winnowing and included thoroughly rubbing the grains in water for a few minutes, and removing all upper floating grains and impurities.

The clean grains were crushed with a plate disc mill (AMUDA, India), passed through a 2 x 2 mm plastic sieve, and sieved with a 0.7 x 0.7 mm metallic sieve, to obtain separately grits, hulls and a fine fraction (fines). The grits were washed by rubbing them by hand for a few minutes in water and then a further soaking in the water for about 2 h. Meanwhile, the embryo and remaining hulls were discarded and added to the hulls previously collected as waste during screening. The washed grits and fines were mixed and the mixture finely ground with the plate disc mill. The resulting meal was kneaded while adding water to obtain a dough (*mawe*). The *mawe* was allowed to ferment naturally, one sub-sample for 24 h and the second one for 72 h. Fermented *mawe* was then cooked into *makume*.

Ogi was prepared following the traditional processing method (Fig. 2) described by Nago (1997). Three replicates of 5 kg of maize (total fumonisin level = 3.35 ± 0.05 mg kg^{-1} and total aflatoxin level > = 22.00 ± 0.26 µg kg^{-1}) were sorted, winnowed, not washed, but precooked for 5 – 10 min. at 90 – 100 °C. Precooking consisted in initially boiling water and soaking the grains in this water not on fire but on ground for 5 – 10 min. The precooked maize was steeped in water for 24 h, milled in a plate disc mill, and sieved in water with a muslin cloth to discard hulls and embryo. The resulting dough (*ogi*) underwent a natural fermentation process, one sub-sample for 24 h and the second one for 72 h. The fermented *ogi* was then used to cook *akassa*, a fermented paste like *makume* obtained from *mawe*.

Owo was prepared following the traditional processing method (Fig. 3). Three replicates of maize (5 kg) (total fumonisin level = 2.89 ± 0.08 mg kg^{-1} and total aflatoxin level > = 22.00 ± 0.26 μg kg^{-1}) were sorted, winnowed, not washed, and milled in a plate disc mill to obtain *lifin*. A suspension of *lifin* was cooked in water to obtain *owo*.

Laboratory analyses

Moisture content of maize samples was determined at each step in the processing of each product. Three replicate samples of 5 g of each were dried to a constant weight in a forced-air oven (Memmert, Germany) at 105 °C for 24 h (AACC 1986). Fermented *mawe* and *ogi* were sampled after 0, 24 and 72 h of fermentation and pH was measured. Total fumonisin content was determined in samples collected at different steps of processing as indicated in the flow diagram for each product (Fig. 1,2 & 3), with a fluorometer using the VICAM method (VICAM 1998). Total aflatoxin content in maize was also measured in the same samples with a fluorometer using the VICAM method (VICAM 1998). Levels of both aflatoxin and fumonisin in each sample, initially measured on wet basis, were calculated on dry basis. Total aflatoxin and fumonisin measurement was performed during processing on the following intermediate products:

- *Mawe* production: raw maize, washed maize, washed grits, hulls, fines, *mawe*, fermented *mawe*, and *makume*.

- *Ogi* production: raw maize, clean maize, dough + screenings, hulls, *ogi*, fermented *ogi*, and *akassa*.

- *Owo* production: raw maize, clean maize, *lifin* (maize meal) and *owo*.

Statistical analyses

Statistical analyses were performed using SPSS for Window version 10.0 (SPSS Inc., Chicago, Illinois). Analysis of variance (ANOVA) and Tukey's HSD test were used to compare the means of the total aflatoxin and fumonisin levels measured in samples collected at different processing steps. Mean total aflatoxin and fumonisin were transformed to log (x+ 1) before analyses, but the data are presented untransformed.

RESULTS

Fate of aflatoxin and fumonisin during preparation of mawe and makume

Total aflatoxin and fumonisin levels in maize products during the preparation of *mawe* and *makume* are shown in Table 1. Both aflatoxin and fumonisin significantly decreased during the processing ($p < 0.01$). Total aflatoxin level decreased from 15.28 μg kg^{-1} in the raw maize to a non-detectable level in *mawe*. Aflatoxin was not detected in *makume*. A 91 % reduction was already observed after sorting, winnowing and washing of the raw maize. No aflatoxin was detected in discarded hulls, embryo and in fines (screenings).

Total fumonisin in maize followed the same trend as that for aflatoxin (Table 1). Levels decreased from 1.99 mg kg^{-1} in the raw maize to not being detected in *mawe*. Fumonisin was not detected in *makume* (Table 1). Initial maize cleaning induced a significant reduction of 74 % of fumonisin in maize. In contrast to aflatoxin, 0.41 mg kg^{-1} and 0.38 mg kg^{-1} of fumonisin was detected in the discarded hulls, embryo and in the fines, respectively.

Neither aflatoxin nor fumonisin were detected in the non-fermented *mawe* and consequently assessment of fermentation effect was not possible (Table 1). The assessment of cooking effect during the preparation of *makume* was not possible as well, as the toxins were at undetectable levels.

Fate of aflatoxin and fumonisin during the preparation of ogi and akassa

Both aflatoxin and fumonisin levels significantly decreased ($p < 0.01$) during the production of *ogi* and *akassa* (Table 2). An 80 % reduction (Table 4) of the total aflatoxin level was observed from the raw maize to *ogi* (from $> = 22.00$ to 4.50 μg kg^{-1}). Aflatoxin was detected in *akassa*, but the level was quite low (1.83 μg kg^{-1}), corresponding to a significant reduction of about 92 % (Table 4). Initial maize cleaning in this case resulted in an aflatoxin reduction of 61 %. A significant level of aflatoxin (7.55 μg kg^{-1}) was detected in the discarded hulls and embryo. This was about 34 % of the level found in the raw maize.

Total fumonisin level also decreased during processing, but less than in the case of aflatoxin (Table 2). A 29 % decrease (Table 4) was observed from the raw maize to *ogi* (from 3.35 mg kg^{-1} to 2.37 mg kg^{-1}). Fumonisin level in *akassa* was 1.74 mg kg^{-1} (Table 2).

corresponding to about 48 % of the level in the raw maize (Table 4). A fumonisin level of 2.35 mg kg^{-1} was detected in the discarded hulls and embryo.

Fermentation gave rise to significant differences in aflatoxin levels in fermented and non-fermented *ogi* ($p < 0.05$), with 18 % reduction between the latter and the former product. This difference, however, was not significant in the case of fumonisin, although there was a reduction of 13 % ($p > 0.05$). No significant differences were found between the aflatoxin and fumonisin levels in *ogi* whether fermentation of this product lasted 24 h or 72 h ($p > 0.05$).

Cooking 24 h-fermented *ogi* to *akassa* did not significantly affect the aflatoxin or fumonisin content. In contrast, mycotoxin levels were significantly lower (1.83 µg kg^{-1} for aflatoxins, 1.74 mg kg^{-1} for fumonisins) in the *akassa* from 72 h-fermented *ogi* than in the *akassa* from 24 h-fermented *ogi* (3.72 µg kg^{-1} for aflatoxins, 2.18 mg kg^{-1} for fumonisins) ($p < 0.05$).

Fate of aflatoxin and fumonisin during the preparation of owo

The preparation of owo had a significant effect on mycotoxin levels (Table 3). A significant decrease in aflatoxin levels was observed from the raw maize ($> = 22$ µg kg^{-1}) to *lifin* (maize meal) (12.62 µg kg^{-1}) ($p < 0.01$), with a meaningful reduction of 37 % after initial maize cleaning prior to milling. No further significant reduction occurred during cooking of maize meal to *owo*.

Fumonisin decreased from 2.89 mg kg^{-1} in raw maize to 1.45 mg kg^{-1} in maize meal, with a 45 % reduction after initial maize cleaning. Also in this case, cooking maize meal to *owo* did not significantly reduce fumonisin level ($p > 0.05$).

DISCUSSION

Results of this study have shown that processing maize into traditional products can significantly reduce levels of both aflatoxin and fumonisin up to 93 %. This indicates that elimination of mycotoxins in naturally contaminated maize is, to a certain extent, possible using such food processing techniques. Reduction of mycotoxins was more substantial during the production of *makume* (*mawe*) and *akassa* (*ogi*) than in the preparation of *owo*. This might be due to the fact that techniques for making *makume* and *akassa* involve critical steps for

mycotoxin reduction. Shephard *et al.* (2002) also found a low reduction of fumonisin level (23 %) in South African stiff porridge, which has a method of processing similar to that of *owo*.

Significantly less fumonisin was removed by cleaning maize during the preparation of *ogi* and *akassa* than during the preparation of *mawe* and *makume*. This might be due to the fact the initial cleaning process during the preparation of *ogi* and *akassa* only consisted in sorting and winnowing, not washing, whereas in the case of the preparation of *mawe* and *makume*, maize was sorted, winnowed and also washed. Moreover, two different processors were used for preparing the products; the one who prepared *mawe* and *makume* was much stricter in cleaning the maize than the other who prepared *ogi* and *akassa*.

Some operations linked to the preparation of maize in Benin appeared to have been very effective in significantly reducing mycotoxins. Simple cleaning by sorting, winnowing and/or washing the contaminated maize grains reduced mycotoxin levels from 18 to 91 %. Higher levels of aflatoxin and fumonisin are generally found in visibly mouldy grains (Rheeder *et al.* 1992, Marasas 1995, Shephard *et al.* 1996, Desjardins *et al.* 1998, Sinha 1998). Systematic disposal of all visibly mouldy, insect-damaged and broken grains, and impurities could be useful in reducing toxin levels in maize. However, hand-sorting visibly mouldy grains with the aim of substantially reducing mycotoxin levels is likely to depend on the ability of the people responsible for this activity. People trained to easily recognise diseased grains are apparently more efficient at achieving this goal (Desjardins *et al.* 2000). Removal of screenings from maize bulk reduces fumonisin levels (Sydenham *et al.* 1994). Likewise, substantial amounts of fumonisin (up to 74 %) were removed by simply washing maize grains, immersing them in water and by removing the upper floating fraction, as contaminated grains generally have a low density (Shetty and Bhat 1999).

Crushing and dehulling maize during *mawe* production has been also identified as a critical operation for mycotoxin reduction, by removing the grain pericarp and embryo. In the present study, recovery of fumonisin for instance in maize after crushing and dehulling was almost negligible. This finding provides additional evidence that removal of pericarps and embryo of maize grains, mechanically or chemically, can also play an important role in the reduction of fumonisins in naturally contaminated maize (Sydenham *et al.* 1995, Canela *et al.* 1996, Katta *et al.* 1997, Bouraima 2001, FDA 2001, Voss *et al.* 2001).

The crushing and dehulling of maize did not influence aflatoxin contamination during the preparation of *mawe*, since no toxin was detected in the discarded hulls and embryo. Aflatoxin levels were already so low in the cleaned grains that levels in the hulls and embryo were below detection. In the case of *ogi*, a significant level of aflatoxin was, however,

recovered in the discarded hulls and embryo after sieving. The aflatoxin levels were still so high in the dough obtained after milling, prior to sieving, that meaningful quantities are likely to be detected in the hulls and embryo. This suggests that aflatoxin distribution in maize fractions during processing may be influenced by contamination levels (Lopez-Garcia and Park 1998).

Fermentation did not appear to have a significant impact on the levels of mycotoxins in products considered in this study. Only 18 % and 13 % reduction of aflatoxin and fumonisin levels respectively were observed during fermentation of *ogi*. Even prolonging the fermentation time from 24 h to 72 h did not significantly affect mycotoxin levels in maize products. Previous studies have presented similar results (Bothast *et al.* 1992, Kpodo *et al.* 1996, Desjardins *et al.* 2000, Kpodo *et al.* 2000). Kpodo *et al.* (1996) explained persistence of aflatoxin during the fermentation process by the presence of aflatoxin precursors in maize grains and the reduction of pH.

There was no evidence that cooking has a significant effect on the reduction of mycotoxins during production of *makume*, *akassa* or *owo*. In all cases, cooking did not last more than 30 min. and is, therefore, unlikely to significantly reduce mycotoxin levels. Kpodo *et al.* (1996) found that ordinary cooking of fermented maize dough for a three-hour period resulted in up to 80 % reduction of aflatoxin level. These authors suggested that degradation of aflatoxin during the cooking process might be favoured by moist conditions. More recently, Shephard *et al.* (2002) using commercial maize meal, found a reduction of fumonisin levels of 23 %, after only 20 min of cooking. Aflatoxin and fumonisin are usually reported to be heat-stable, and are not easily destroyed by ordinary cooking (Alberts *et al.* 1990, Scott 1993, Sinha 1998), except at high temperatures (more than 150 °C for fumonisin) (Bolger *et al.* 2001). However, aflatoxin can be partially removed by cooking, especially when this occurs under pressure in moist conditions (Sinha 1998).

Another processing step probably responsible for significant mycotoxin reduction was the way the *ogi* supernatant was used during the cooking of *akassa*. The supernatant from 72 h-fermented *ogi* was replaced with simple water and discarded or used to produce beverages when the acidity levels were inordinately high to give an acceptable *akassa*. This may explain why both aflatoxin and fumonisin contents were reduced in *akassa* prepared from 72 h-fermented *ogi*. Here, mycotoxins probably diffused in the *ogi* supernatant, which was discarded. This observation is in agreement with findings of Canela *et al.* (1996) who found fumonisin B_1 to migrate from contaminated maize grains to the steeping water after 48 hours. Voss *et al.* (2001) also showed that fumonisins are mostly found in the rinsing liquid during

processing of tortillas. While discarding *ogi* supernatant constitutes a significant decontamination process, its use to prepare beverages, which is a common practice in West Africa, may be harmful to consumers and should be discouraged.

Some traditional food processing techniques in Africa may potentially be useful for detoxifying foods from mycotoxin contamination. However, there is increasing evidence that mycotoxin molecules, specifically fumonisin, bind with starch to form a complex that cannot be detected (Bullerman and Tsai 1994, Kim *et al.* 2002). Alternatively, they react with reducing sugars such as D-glucose to give sugar adducts (Howard *et al.* 1998, Seefelder *et al.* 2001, Voss *et al.* 2001), or are hydrolysed to the aminopolyols AP_1 and AP_2 (Dombrink-Kurtzman *et al.* 2000, Voss *et al.* 2001). Further research is, therefore, needed to clarify whether the mycotoxins apparently lost during the preparation of foods are really destroyed, hydrolysed or bound to the food matrix to become non-recoverable.

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Table 1: Mean total aflatoxin and fumonisin concentrations in maize products at each processing stage during the preparation of *mawe* (dry basis)

Maize products	Dry matter content (%)	pH	Mean total aflatoxin (μg kg^{-1})		Mean total fumonisin (mg kg^{-1})	
Raw maize	84.51 ± 0.06		15.28 ± 0.32	a	1.99 ± 0.06	a
Washed maize	84.35 ± 0.04		1.42 ± 0.06	b	0.54 ± 0.03	b
Washed grit	55.90 ± 0.32		nd	c	nd	e
Mawe	54.58 ± 0.27	5.90 ± 0.14	nd	c	nd	e
Fermented *mawe* 24 hours	53.02 ± 0.28	4.14 ± 0.08	nd	c	nd	e
Fermented *mawe* 72 hours	51.01 ± 0.32	3.70 ± 0.10	nd	c	nd	e
Makume 24 hours	39.01 ± 0.24		nd	c	nd	e
Makume 72 hours	40.17 ± 0.34		nd	c	nd	e
Hulls + embryo	82.99 ± 0.17		nd	c	0.41 ± 0.15	c
Fines (screenings)	83.29 ± 0.21		nd	c	0.37 ± 0.06	d

Means within a column followed by the same letter are not significantly different ($P > 0.05$)

nd = not detected = level < 1 μg kg^{-1} for aflatoxins; level < 0.25 mg kg^{-1} for fumonisins.

Table 2: Mean total aflatoxin and fumonisin concentrations in maize products at each processing stage during the preparation of *ogi* (dry basis)

Maize products	Dry matter content (%)	pH	Mean total aflatoxin ($\mu g\ kg^{-1}$)		Mean total fumonisin ($mg\ kg^{-1}$)	
Raw maize	84.19 ± 0.07		22.00 ± 0.26	a	3.35 ± 0.05	a
Steeped maize	84.21 ± 0.06		8.62 ± 0.09	b	2.76 ± 0.11	b
Dough + screenings	43.65 ± 0.57		7.79 ± 0.12	c	2.75 ± 0.09	bc
Ogi	42.10 ± 0.47	6.20 ± 0.10	4.50 ± 0.20	d	2.37 ± 0.22	cd
Fermented *ogi* 24 hours	40.40 ± 0.61	4.00 ± 0.10	3.69 ± 0.03	e	2.07 ± 0.12	d
Fermented *ogi* 72 hours	39.97 ± 0.48	3.05 ± 0.15	3.65 ± 0.05	e	2.28 ± 0.14	d
Akassa 24 hours	43.79 ± 0.32		3.72 ± 0.02	e	2.18 ± 017	d
Akassa 72 hours	36.56 ± 0.29		1.83 ± 0.02	f	1.74 ± 0.07	e
Hulls + embryo	42.19 ± 0.19		7.55 ± 0.43	c	2.35 ± 0.03	d

Means within a column followed by the same letter are not significantly different (P >0.05)

Table 3:   Mean total aflatoxin and fumonisin concentrations in maize products at each processing stage during the preparation of *owo* (dry basis)

Maize products	Dry matter content (%)	Mean total aflatoxin (µg kg^{-1})		Mean total fumonisin (mg kg^{-1})	
Raw maize	84.67 ± 0.02	22.00 ± 0.26	a	2.89 ± 0.08	a
Clean maize	84.62 ± 0.04	13.79 ± 0.19	b	1.61 ± 0.09	b
Maize meal	86.15 ± 0.10	12.62 ± 0.43	c	1.38 ± 0.02	c
Owo	70.82 ± 0.18	13.13 ± 0.25	bc	1.45 ± 0.05	c

Means within a column followed by the same letter are not significantly different (P > 0.05).

Table 4:   Mean percentage of reduction in total aflatoxin and fumonisin concentrations during maize processing

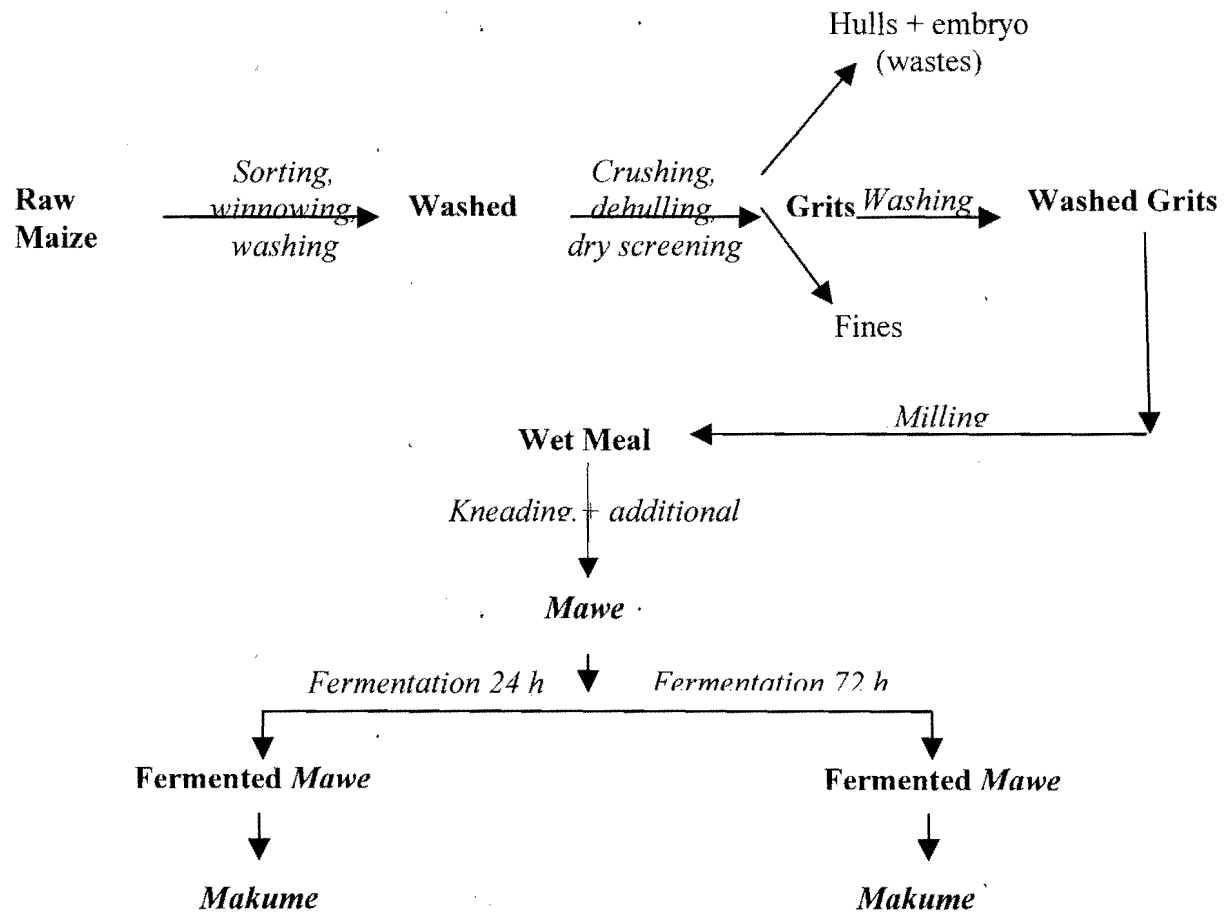| Maize processing	Mean percentage of mycotoxin reduction (%)	
	Total aflatoxin	Total fumonisin
Raw maize → *mawe*	> = 91	> = 87
Raw maize → *mawe* → *makume*	> = 93	> = 87
Raw maize → *ogi*	80	29
Raw maize → *ogi* → *akassa*	92	48
Raw maize → *owo*	40	48

Figure 1:   Flow diagram outlining the preparation of *mawe* and *makume*, two maize-based
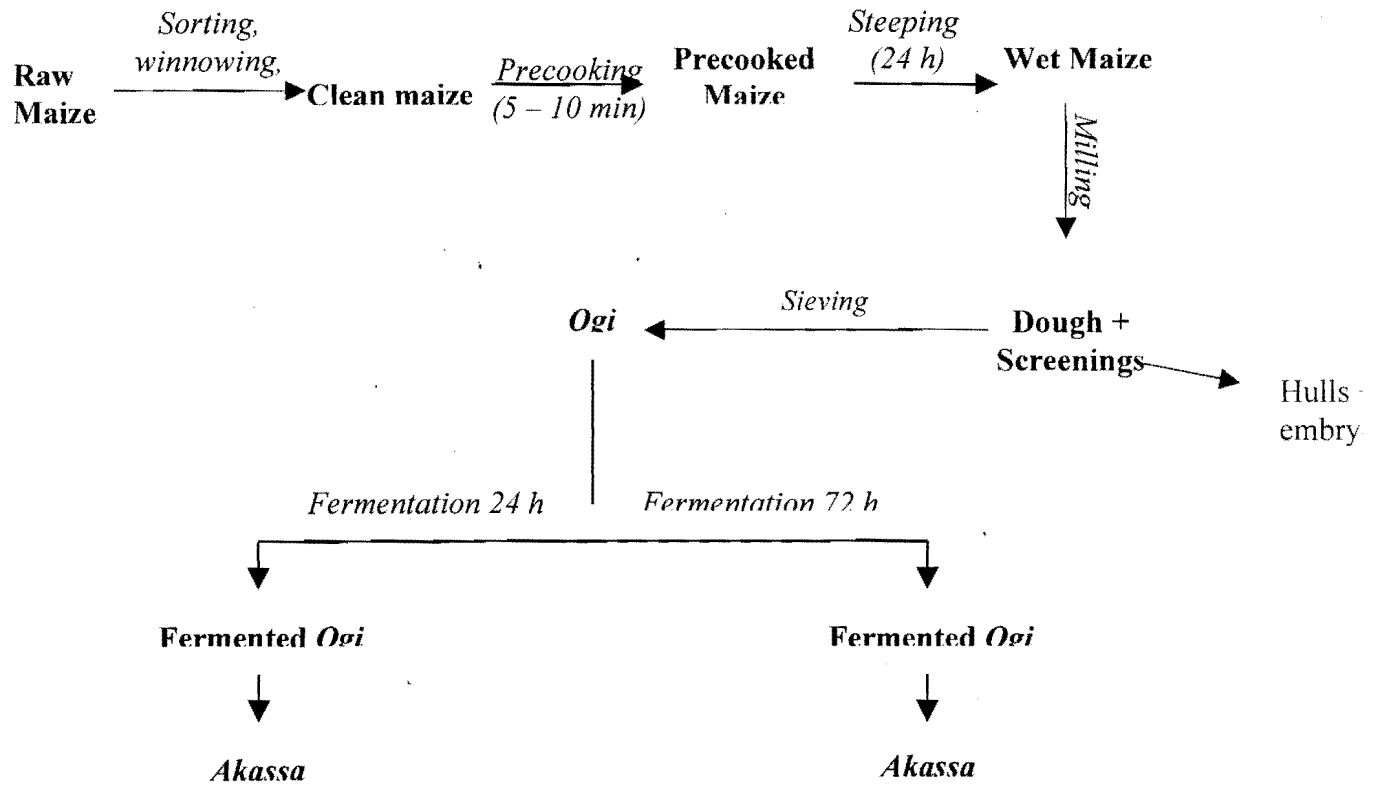
foods of Benin

Figure 2:   Flow diagram outlining the preparation of *ogi* and *akassa* in Benin

Raw Maize

Sorting
Winnowing

↓

Clean Maize
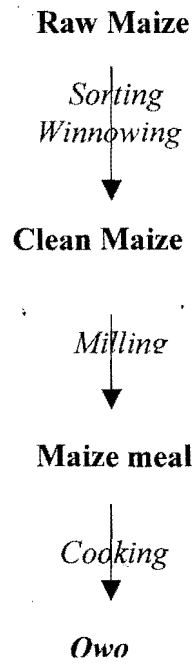
Milling

↓

Maize meal

Cooking

↓

Owo

Figure 3:   Flow diagram outlining the preparation of *owo* in Benin